

ANALYSIS OF RECTANGULAR DIELECTRIC RESONATOR ANTENNAS EXCITED THROUGH A SLOT OVER A FINITE GROUND PLANE

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Introduction

Recently, the Dielectric Resonator Antenna (DRA) radiating element has been the subject of considerable interest due to its small size and high efficiency. The rigorous analysis of DRA elements, however, has been largely restricted to rotationally symmetric shapes [1-2]. Other shapes have been analyzed, however, often based on an infinite ground plane assumption [3] which restricts the use of the DRA as a single element for some applications that require finite size ground plane. Various numerical techniques have been used in the analysis of the DRA. The spherical mode expansion was used to analyze a hemispherical DRA [2]. The Surface Integral Equation with the Method of Moments (SIE/MoM) has been used to analyze a rotationally symmetric DRA [1]. The modal expansion method with some approximation was used in [3] to analyze the rectangular DRA, and the Finite Difference Time Domain (FDTD) method has been used to analyze a rectangular DRA and cylindrical DRA with a staircased cell approximation [4,5]. Here the rectangular DRA is considered over a finite ground plane with a microstrip slot excitation. The SIE/MoM is used with the RWG triangle basis function expansion [6,7]. Using the triangle basis functions allows modeling of arbitrarily shaped objects. Also, the FDTD method is used to analyze the same problem for the purpose of verifying both methods. The effect of the ground plane size and the dielectric substrate truncation is studied.

Methods of Analysis

(a) Method of Moments: An SIE/MoM formulation for a 3D object consisting of arbitrarily shaped conducting and/or dielectric bodies has been developed [7,8]. The object may have general junctions of conducting and dielectric surfaces. Any distinct material boundary surface is triangulated to use the RWG basis functions [6]. Invoking the equivalence theorem, the original problem is reduced to a coupled set of N_R (the number of dielectric regions) equivalent problems, to which the standard SIE/MoM procedure is applied using the E-PMCHW formulation [9]. A delta-gap voltage source is considered between the microstrip transmission line and ground plane.

(b) Finite-Difference Time-Domain Method: The standard Yee Algorithm with the staircase approximation is used [10]. Because of the rectangular geometry, however, this results in no additional approximations. To truncate the computational domain, the second order Mur absorbing boundary condition is used in the six directions. A soft voltage source with an internal resistor is implemented between the microstrip transmission line and ground plane to speed up the solution.

Numerical Results

A rectangular resonator fed by a microstrip line through a slot as shown in Fig. 1 is taken as a test case to study the effect of the finite ground plane size on the far-field radiation patterns. The parameters of the DRA are the same as in [3], but with different ground plane dimensions as given in Table 1. The dielectric constants of the DRA and the substrate are 10.8 and 10, respectively, and the substrate thickness is 0.64 mm. The DRA dimensions are 15 mm \times 3 mm \times 7.5 mm; the microstrip-line stub length is 2.2 mm measured from the center of the slot, which is 1.2-mm wide and 6.1-mm long; the total length of the microstrip line is 17.2 mm, and it has a width of 0.6 mm. The resonant frequencies of the all DRA's in Table 1 were found to be around 7.4 GHz. The far fields are computed at the resonant frequency and normalized to the peak value. The far fields are computed using both the MoM and FDTD for the cases in Table 1, and are found to have excellent agreement with each other, with a difference less than 0.2 dB in the forward direction. A sample of this comparison is shown in Fig. 2 for case 5. Fig. 3 shows the computed far fields using MoM to investigate the effect of the dielectric substrate truncation on the radiation patterns. As expected, the effect of the substrate truncation is found to be minimal. Fig. 4 shows the effect of ground plane size on the radiation patterns. A significant effect is observed on the radiation patterns. For case 1 the dielectric resonator is placed off the center of the ground plane. Therefore, its E-plane pattern is not symmetric around the dielectric resonator center.

Acknowledgment

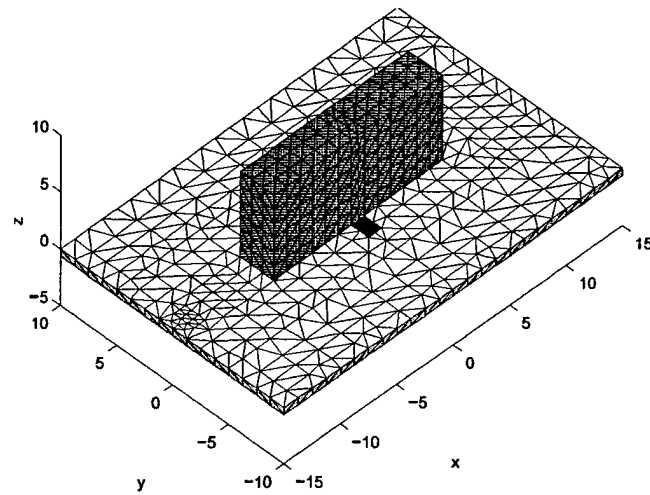
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REFERENCES

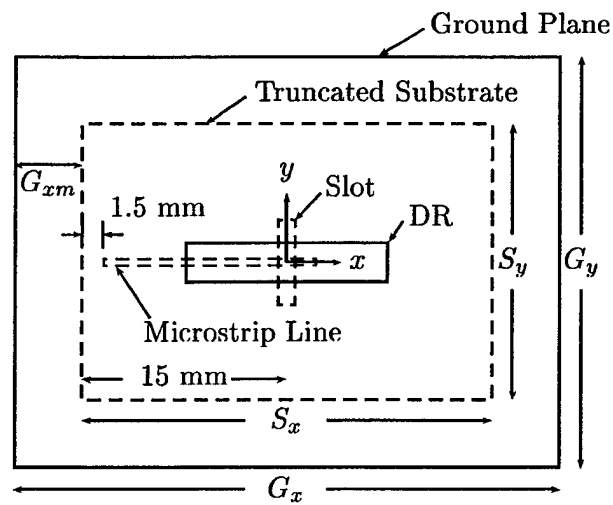
- [1] G.P. Junker, A.A. Kishk, A.W. Glisson, "Input impedance of aperture coupled dielectric resonator antenna," *IEEE Trans. Antennas Propagat.*, vol. 44, no. 5, pp. 600-607, May 1996.
- [2] Kishk, A. A. and G. Zhou, and A.W. Glisson, "Analysis of dielectric resonator antennas with emphasis on hemispherical structures," *IEEE Antennas Propagat. Magazine*, vol. 36, no. 2, pp. 20-31, April 1994
- [3] Y.M.M. Antar and Z.Fan, "Theoretical investigation of aperture-coupled rectangular dielectric resonator antenna," *IEE Proc.-Microw. Antennas Propaga.*, vol.143, Apr. 1996.
- [4] S. M. Shum and K. M. Luk, "Analysis of aperture coupled rectangular dielectric resonator antenna," *Electronics Lett.*, vol. 30, pp. 1726-1727, 1994.
- [5] S. M. Shum and K. M. Luk, "FDTD analysis of probe-fed cylindrical dielectric resonator antenna," *IEEE Trans. Antennas Propagat.*, vol. 46, no. 3, pp. 325-333, Mar. 1998.
- [6] S. M. Rao, D. R. Wilton, and A. W. Glisson, "Electromagnetic scattering by surfaces of arbitrary shape," *IEEE Trans. Antennas Propagat.*, vol. AP-30, pp.409-418, May 1982.
- [7] J. Shin, A. W. Glisson, and A. A. Kishk, "Modeling of general surface junctions of composite objects in an SIE/MoM formulation," submitted to *ACES 2000 Conference*, 2000.
- [8] J. Shin, A. W. Glisson, and A. A. Kishk, "Analysis of combined conducting and Dielectric structures of arbitrary shapes using an E-PMCHW integral equation formulation," submitted *AP-S 2000* (this symposium), 2000.
- [9] A. A. Kishk and L. Shafai, "Different formulations for numerical solution of single or multibodies of revolution with mixed boundary conditions," *IEEE Trans. Antennas Propagat.*, vol. AP-34, pp.666-673, May 1986.
- [10] K. S. Yee, "Numerical solution of initial boundary value problems involving Maxwell's equations in isotropic media," *IEEE Trans. Antennas Propagat.*, vol. AP-14, pp.302-307, 1966.

TABLE 1. DRA dimensions. Unit : mm

Case No.	Substrate ($S_x \times S_y$)	Ground Plane ($G_x \times G_y$)	G_{xm}
1	25×10	25×10	0
2	30×20	30×20	0
3	25×10	30×20	0
4	ditto	50×40	10
5	ditto	70×60	20
6	ditto	90×80	30



(a) 3D view (case 2)



(b) Top view

Fig. 1. Dielectric resonator antenna with a finite ground plane.

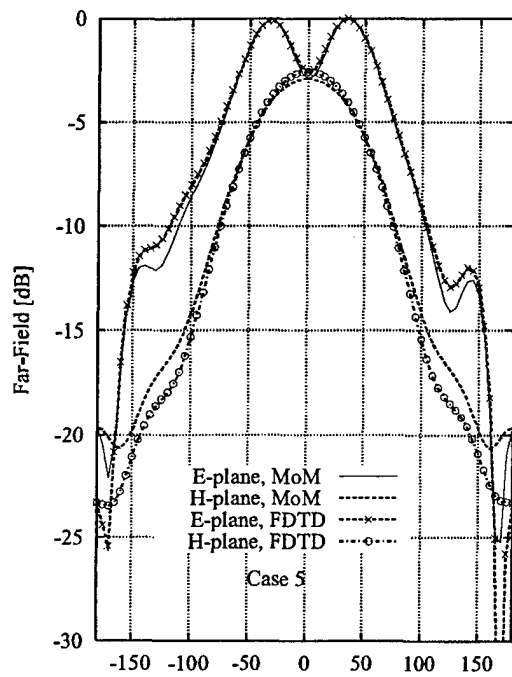


Fig.2. Comparison of MoM and FDTD results

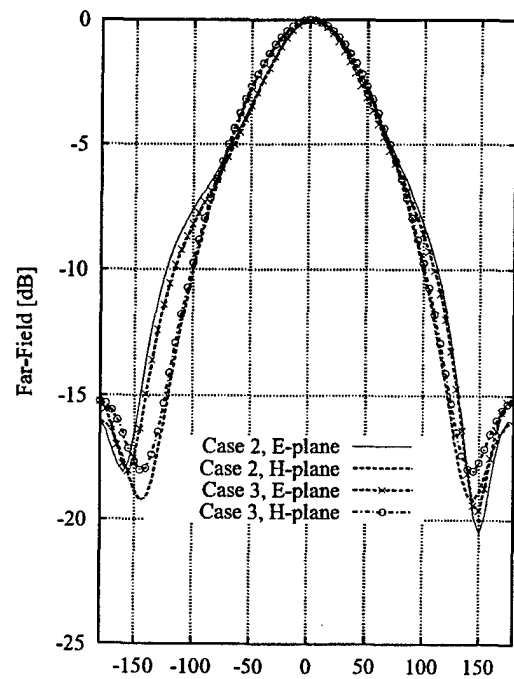


Fig.3. Effect of truncated substrate.

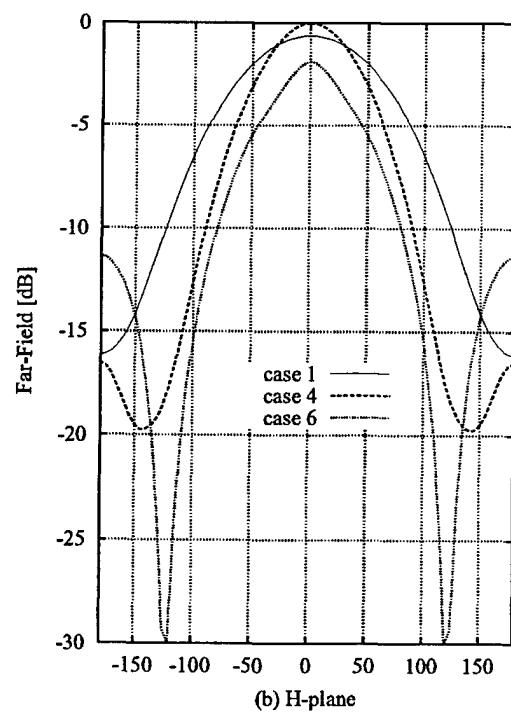
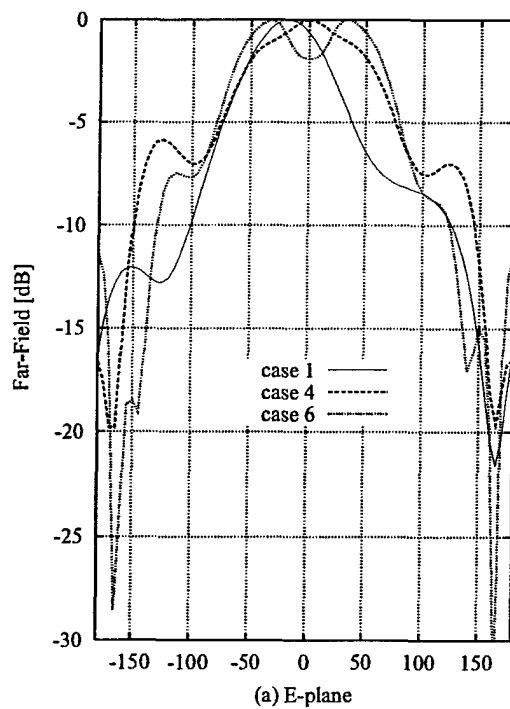


Fig. 4. Effect of ground plane size on radiation patterns as functions of observation angle θ .